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METHODS OF RECOVERY AND SOME CHEMICAL PROPERTIES OF TRANSPLUTONIUM ELEMENTS

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Introduction

The problem of producing of transplutonium elements from the materials irradiated by the large integrated neutron flux is associated with the solution of two principal tasks: separation of transplutonium elements from the fission products and recovery of pure individual elements. The main difficulty of the transplutonium element recovery lies in the similarity of their chemical properties with those of rare earth fission products. For the last years a number of chemical flowsheets which permit to recover transplutonium elements with high efficiency was developed.

The present paper throws some light on some methods of production and recovery of transplutonium elements and the results of physical and chemical investigations of the elements with respect to complexing and extraction of phosphororganic compounds.

I.The experimental base for the transplutonium element production.

The reactor SM-2 and radiochemical laboratory were constructed in NIIAR for transplutonium elements to accumulate,recover and study their chemical and physical properties.

25 YEAR RE-REVIEW

The neutron flux in the centre channel of SM-2 is 2.10^{15} n/sec.cm^2

A single load of starting materials in the transplutonium reactor channels approaches 200g.

The radiochemical laboratory comprises two adjacent buildings: a hot and cold ones. The cold building is designed to investigate the trace concentrations of radioactive isotopes. Sixteen cells are available, six of them are two-storeyd. The size of the most cells is 2,4x1,8x2.4m. Three cells are 4.8x1.8x2.4m in size. The cell shielding consisting of concrete with specific density of $3.6t/m^3$ permits to work with the radioactivity up to 100,000 curie. According to their purpose the shield cells are devided into technological and auxiliary ones.

The technological cells are grouped due to the basic processes occurred (three cells in every group):the extraction process cells, the cells of ion exchange processes and the cells of precipitating and unaqueous processes.

The auxiliary cells are intended for reception and storage of specimens,their cutting, weighing, linear measurements and dissolution.

The auxiliary cells involve a transfer cell and sample and storage ones.

In the hot building the semi-hot research laboratories are also housed:physico-chemical,of complex compounds,of isotopes, radiometric,spectral,mass-spectral,X-ray diffraction,analytical, target,of the extraction,ion exchange,precipitating and unaqueous process.

The semi-hot laboratories are equipped by 56 special boxes with the cast iron or steel shield of 10-150mm in thickness.

348

— 2 —

The remote control in boxes and cells is realized by electro-
mechanical, master-slave and ball-swivel manipulators.

All the laboratories of the hot fuilding are placed in three
zones: the first zone is an operating zone of cells boxes and techno-
logical canyons, in the second one the repair corridors are placed and
the third zone is operating rooms.

II. Complexing of Am^{3+} and Cm^{3+} in aqueous solutions

The Am and Cm complex ion composition and stability with a
number of organic and inorganic addends were examined by the cation-
exchange method(1-3). The study was performed with the trace concentra-
tions of the Am^{241} and Cm^{242} isotopes(the concentration of Am in
operating solutions was 10^{-7} mole/l, that of curium was 10^{-10} mole/l). The
experiment consisted of the determination of the distribution coeffi-
cient of an element (φ) between the cation-exchanger KU-2 or Dowex-
50x8 in NH_4^+ or Na^+-forms with variable concentrations of addends in
the solution. The distribution coefficients were obtained in static
conditions and calculated from the difference between the metal
concentration in solution prior to the experiment(C_0) and after the
state of equilibrium between the solution and resin has been settled
(C_m).

$$\varphi = \frac{C_0 - Cm}{C_m \cdot \frac{m}{v}}$$

where m-is the load of the resin (mg), v is the solution volume(ml).
All the experiments were performed with constant ionic strength
maintained by NH_4Cl or $NaClO_4$.

The correlation between the metal distribution coefficient(φ)
and the complex stability constants is determined by the equation:

34 8

$$\mathcal{G} = \mathcal{G}_0 \frac{1 + \sum_{j=1}^{s} 1_j \left[A \right]^1}{1 + \sum_{i=1}^{n} \beta_i \left[A \right]^i} \qquad (2)$$

where A is an equilibrium free addend concentration, β_i is an over-all stability constant of MA_i, 1_j are constants, related with the complex cation sorption, s is a number of the complex cations, $\mathcal{G}_0$ is the distribution coeffisient without addends.

Thus, the obtained experimental dependence on A allows to determine composition of the complexes and calculate their stability constants. If the positive charge of metal is more than the negative charge of addend the complex cations are present at the system sorption of which by the resin may strongly complicate calculations.

But no sorption of complex cations was found to exist in any complex systems examined; it was obtained, mainly, from calculations and in case of the phosphate system from the direct analyses of the composition of species sorbing on the cation-exchanger from the solution with lanthanum and phosphate-ions. Terefore, the complex stability constants were calculated from the simplified version of formula (2), i.e. the terms with 1_j in numerator were omitted.

The americium and curium complexing with inorganic addends was investigated in nitrate, thyocyanate, sulfate and phosphate systems. These were studied in weak acid solutions at pH=1.5-4.0. Since in this case three types of anions, i.e. $H_2PO_4^-$, HPO_4^{2-} and PO_4^{3-}, are present at phosphate solutions, the special study was undertaken to determine the composition of anions forming complexes. The character of dependence of the Am^{3+} sorption from phosphate solutions on pH showed that the complexing with the $H_2PO_4^-$-ions occured under given conditions.

348

- 4 -

On the basis of the experiments the complex ions in the systems investigated were found to be as MNO_3^{2+}; MSO_4^+; $M(SO_4)_2^-$; $MSCN^{2+}$; $M(SCN)_3^0$ (where M—Am or Cm) and $Am\ H_2PO_4^{2+}$;

Table 1 gives the general stability constants of these complex ions at the ionic strength of the experiment (β) and zero ionic strength (β_0) (recalculation was done with the activity coefficients derived from Davis's equation).
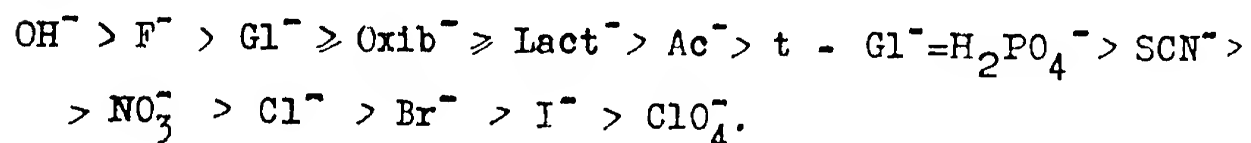
The stability constants of some complex ions for trivalent lanthanides $(Ce^{3+}, Pm^{3+}, Y^{3+})$ are presented here. The Am and Cm complexing with some organic anions important for separation and purification of the actinides was investigated. The composition and stability of the Am^{3+} and Cm^{3+} complexes with lactate (Lact$^-$) and α-hydrooxiisobutyrate (Oxib)-ions were examined with the constant pH of the solution (about 4.0) and the free addend concentration from 3.10^{-4} to 3.10^{-1} mole/l. Under these conditions the complex ions $MR\ Lact^{2+}$, $M(R\ Lact)_2^+$, $MOxib^{2+}$ were found to exist and their stability constants were calculated. The study of the Am^{3+} and Cm^{3+} complexing with oxalat-ions was conducted at the variable pH(2-4) in the addend concentration range $(C_2O_4^{2-}) 10^{-6} - 3.10^{-3}$ mole/l; the stability constants of the complex ions $MC_2O_4^+$ and $M(C_2O_4)_2^-$ were determined. The stability constants of the oxalate americium complexes are in a close agreement with those defined earlier by the solubility (4) .

The Am^{3+} complexing in acetic solutions was also studied. Three sets of experiments were performed with various ionic strength of the solution - 0.2, 0.5 and 1.0. The experiments showed that at the free addend concentration from $1.5.10^{-3}$ to 5.10^{-1} mole/l the complex ions $Am\ Ac^{2+}$ and $Am\ Ac_2^+$ are predominant in the solution. The complex ion stability constants calculated for three values of ionic strength were then extrapolated to zero ionic strength using Debye-

3 4 8

- 5 -

Huckel-Guggenheim's equation in the form proposed by V.P.Vasiliyev5.

Table II gives the concentration and thermodynamic stability constants for the americium and curium organic complexes. The thermodynamic constants of oxalate complexes were calculated using the activity coefficient from work (6).

These results allow to extend a series of one charged anions proposed by Seaborg (7) on the ground of the stability of their complexes with the actinide ions. Using the data available at present concerning the Pu^{3+} complexing with the OH^--ions (8), the Am^{3+} complexing with glycolat /Gl/and thioglycolat /t-Gl/-ions (9) as well as with halogen ions (10,11) this series for trivalent actinides may be written as:

$$OH^- > F^- > Gl^- \geqslant Oxib^- \geqslant Lact^- > Ac^- > t - Gl^- = H_2PO_4^- > SCN^- >$$
$$> NO_3^- > Cl^- > Br^- > I^- > ClO_4^-.$$

The right part of this series consists of inorganic addends (except the OH^- and F^- ions) which forms relatively weak complexes. The decrease of the inorganic complex stability in general corresponds to the increase of the effective anion radius. Organic addends form stronger complexes, the stability of complexes with $\propto$ -hydro-oxiacids being more than that of acetic complexes due to the additional bond formation M-O. The complexes with aminoacids appears to be stronger to judqe from the analogy with the complexes of trivalent lanthanides (12,13).

As for thioglycolic acid, here, due to the bond M-S weakness the effect predominates resulting from that the electron pair is drawn off by the SH group.

All the americium and curium complexes investigated are more stable than those of the corresponding lanthanides-Eu and Gd, it confirming the presence of 5f - actinide electrones while the

3 4 8

- 6 -

bonds in complexes are formed. It may be noted that difference in the complex strength, for instance, of americium and europium is increased as the addend structure became more complicated. In particular this difference is increased with the increase of the addend dentation.

For the time being it is not possible to establish the simple regularity while comparing the stability of complex ions of Am, on the one hand, and of Cm, on the other hand.

The nitrate, sulfate, oxalate and, probably, chloride complexes are stronger in case of americium, while thiocyanate, lactate α-hydroxyisobutyrate and ethylenediamintetraacete complexes (14) are stronger in case of curium.

It is interesting to note that the same effect is observed when the stability of the europium and gadolinium complexes is compared. Of particular importance is the tendency to the increase of the complex strength for curium (gadolinium) as compared to the complex stability for americium (europium)with the increase of the addend dentation.

The variation of the complex stability during its transfer from americium to curium appears to depend on the structure of addend rather than on the 5-f electron behaviour.
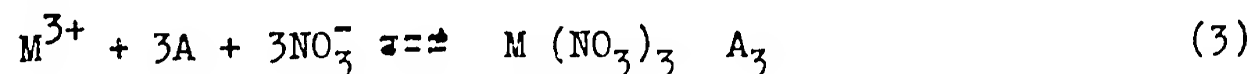
348

- 7 -

III. Extraction of Am, Cm and some rare-earth elements by

neutral phosphororganic compounds

I. Mechanism of the americium, curium and nitric acid
extraction by neutral phosphororganic compounds.

To understand the extraction mechanism and the effect of the
extractant structure on the process the extraction of americium,
curium and nitric acid by a large number of various neutral
extractants was investigated.

The distribution coefficient of the americium and curium was
found to be proportional to the third power of the extractant
concentration in organic phase and the third power of the nitrate
ion concentration in aqueous phase (with the NO_3^- from 0.01 to 1.5m
and constant ionic strength, maintained by NH_4ClO_4).

Thus, for the neutral extractants the extraction process is
expressed as:

$$M^{3+} + 3A + 3NO_3^- \rightleftharpoons M(NO_3)_3 \ A_3 \qquad (3)$$

where A is the extractant molecule.

The constant of this reaction is written as:

$$\tilde{k} = \frac{\left[M(NO_3)_3 \ A_3\right]_{org.}}{\left[M^{3+}\right]_{aq.}\left[NO_3^-\right]^3_{aq}\left[A\right]^3_{org.}} = \frac{\propto}{\left[NO_3^-\right]^3_{aq}\left[A\right]^3_{org.}} \qquad (4)$$

We have determined the extraction process constants of americium
and curium for the most of compounds investigated. Extrapolating the
obtained dependance $\tilde{K}$ on ionic strength (in scal $\log \tilde{k} - \sqrt{\mu}$)one
can obtain the values of the reaction constants at zero ionic
strength, K_0. These are given in table 3 and serve for comparison
of the extractability of the extractants under consideration.

Research on the nitric acid extraction by neutral extractants
revealed that the distribution coefficient of HNO_3 was proportional

348

- 8 -

to the equilibrium acid concentration in aqueous phase and free
extractant concentration in organic phase.Thus, monosolvate is
established to form in all cases. As in case of americium and
curium the reaction constants $(\widetilde{K}_0)$of the nitrous acid extraction
by neutral extractants were calculated;the data are also presented
in table 3.

On the basis of data available one can make a conclusion as
to the extraction mechanism and the effect of the extractant struc-
ture on the extraction of americium, curium and nitric acid.At
present there is no doubt about that the solvate formation by
neutral extractants with the $P = O$ group occurs due to the inter-
action with the free electron pair of phosphoryl oxygen.Therefore,
the introduction of positive group in the extractant,e.g.the alkyl
radical elongation should intensify the extractability.Really,sub-
stitution of one or two butyl radicals by octyl(in ethereal part
of the extractant molecule)increases K_0 both for trivalent actinides
and for HNO_3.On the other hand,substitution in the BEDBP molecule
of all three butyl radicals by octyl finally results in the extracta-
bility decrease. With a great deal of long radicals or when a
radical is strongly elongated the steric factors acquires more
importance which gives rize to the extractability maximum at the
certain radical length.

V.G.Timoshev (15) showed that in a series of di-isobutyl
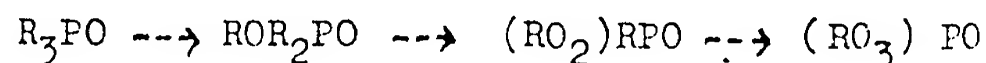ester$(iC_4H_9O)_2RPO$ the extractability grows to $R=C_8H_{17}$;

The present work presents the americium,curium and nitric acid
extraction by the corresponding compounds near maximum;the highest
extraction is observed at $R=C_9H_{19}$.

The introduction in the extractant molecule of the electro-
negative groups sharply reduces the $p=O$ bond polarity and hence

348

- 9 -

suppresses the ability of the bond formation through phosphoryl oxygen.Therefore the extractability of such compounds as di-OEPP, di-OKEP, i-OKEMP, di-OES MP, BEPS,MP is essentially lowered.When introducing two aromatic groups (e.g.cresyl groups) the extractant does not recover any longer americium and curium even at the high concentration of the salting out agent (magnesium nitrate) in aqueous phase. Under these conditions the variation of the metyl radycal posi-tion in the aromatic substituent strongly affecting physical and chemical properties of the extractant changes insignificantly the extractability.

The number of bonds C-O-P in the extractant molecule influences greatly the extraction. In case of nitric acid as well as in case of americium and curium the extractability of compounds is considerably lowered with the increase of the oxigen bonds,i.e. in a seris:

$$R_3PO \dashrightarrow ROR_2PO \dashrightarrow (RO_2)RPO \dashrightarrow (RO_3) PO$$

The extraction dependence on the branching of organic radicals involved in the extractant molecule is especially complicated. For phosphine oxides(R_3PO) and phosphinates $(RO)R_2PO)$ the extractability of the compounds with the normal chain is higher than that with isostructure, the difference being the higher the less oxygen groups exist. However, when passing to phosphonates and phosphates the difference in the extractability becomes less essential.

348

- IO -

IV. Investigation of the Extraction Separation of
Americium and Curium Under Static and Dynamic Conditions

Neutral and acid phosphororganic compounds may be used for the trivalent actinides decontamination from the rare earth fission products. From this point the Am^{3+}, Cm^{3+} and some lanthanide(Pm^{3+}, Ce^{3+})extraction from chloride and thyocyanate solutions was examined.

Data on the distribution coefficient of americium and curium between the LiCl solutions and neutral phosphororganic extractants tributylphosphate (TBP),TOPO and diamil ester of methyl phosphonic acid (DAMP)- are given in table 4. The corresponding data for the acid extractants are presented in table 5. As it is seen on the basis of these data the neutral extractants recover americium and prometium only from the rather concentrate solutions while the acid extractants have the high distribution coefficient with the weak concentrations of LiCl. The best separation of americium and prometium may be provided by DAMP and D2EHPA from the solution with the LiCl concentration more than 9M.

The separation of actinides and lanthanides by the extraction by trioctylamine (TOA) from chloride solutions is described in literature $\left(16, 17\right)$. In the present work americium and prometium extraction by TOA in xylene from the LiCl concentrated solutions was examined. The best results for separation and decontamination from the rare-earth elements are obtained with the concentration about 11M; the distribution coefficient of Am^{3+} being equal to 2.6, that of Pm is 0.03. The difference in the complexing of trivalent actinides and lanthanides with the thyocyanate-ions may be used for the extraction separation. For this purpose the extraction of americium,curium and prometium by TBP, TOPO and DEMP from the ammonium thyocyanate

348

- II -

solutions of various concentrations with pH-1(table 6), and that
by D2EHPA and M2SHPA from 0.1-8m NH_4SCN (table 7) was studied.
These element extraction by the neutral extractants is increased
with the NH_4SCN concentration growth; however the essential difference
between the distribution coefficient of actinides and lanthanides is
not observed. The reverse dependence is seen to occur for the acid
extractants, i.e.the extractability is lowered when the thyocyanate
concentration is increased. As the thyocyanate complex ions of tri-
valent actinides are stronger than those of lanthanides,the americium
and curium extraction is decreased in a higher extent than the
lanthanide extraction with the NH_4SCN concentration increase. It
permits to separate americium and curium from lanthanides by the
extraction of the latter by D2EHPA or M2EHPA from the 6-8M NH_4SCN
solution.

The data obtained under static conditions were then examined
under dynamic conditions using the apparatus of mixer-settler type
and model solutions. Model solutions of the corresponding salt
composition contained americium, a sum of the rare earth fission-
products of 2-year cooling times and rare earth carriers -lanthanum
and cerium. The experiments were performed in a mixer-settler with
13 sections equipped by the stainless steel mechanical mixers
varnished with epoxy resins. The opposed current and semi-opposed
current schemes were used for the extraction.

To separate americium and rare-earth elements the following
systems were studied:0.75M D2EHPA in decane -6M NH_4SCN; 0.75M
D2EHPA in decane -11M LiCl (+0.4M HCl) and 20% TOA in xylene
-11M LiCl(+0.0 M HCl).The thyocyanate (solution was extracted by
the extractor with 7 extracting and 6 washing sections; this produc-
ed the satisfactory americium decontamination from the rare-earth

348

- I2 -

elements (10^3) and gave a high americium yield (99%).

The extraction with D2EHPA was carried out under the same conditions which provided the same americium yield (99%) but the decontamination was much worse (about 10).

The system TOA-LiCl proved to be the most effective one for the group separation of lanthanides and actinides. When extracted by the opposed current scheme on seven extraction and six washing sections americium was separated from the rare-earth elements with the decontamination factor of more than 10^4; the americium yield in the process was 99.9%. These data agree with Ferguson's data (18).

Americium was separated from the rare earth elements by TOA using the semi-opposed current scheme as well. The extraction was carried out using the assembly with 9 sections, one of which contained a mixture of elements and the rest served as washing sections. Due to this process even higher decontamination of americium(10^5) and the yield of 99.9% were obtained; however, in this case the solution volume, containing americium, was 10 times the initial solution.

Thus,the extraction systems described allow completely enough to separate trivalent actinides from the rare-earth fission products.Combining with the preliminary decontamination from other fission products and from the corrosion products of structural materials which does not present a problem one may recover quantitatively high pure americium and curium by these methods.

V.Possible Variants of Schemes of the Extraction and

Decontamination of Americium

It is possible to apply the extraction methods developed to the americium recovery from the wastes of the reprocessing of the plutonium specimens irradiated. In this case in the solutions to

348

reprocess the large amounts of salts (nitrates) and fission products are usually present which succeed considerably the americium content. All the schemes for this solution reprocessing comprise as usual three main stages which may be provided by the extraction processes.

The first necessary stage of any scheme is the americium recovery from the nitrate high salt solution. It may be performed in several ways. One of these ways is the extraction by TBP or D2EHPA.

It is necessary to pre-remove the excess of acid from the solution and make up its pH to 1, for example, by distillating off with steam at $140^{o}C$. The steam consumption then is 2-2.5kg per 1mole HNO_3; the solution obtained has the density of about 1.24 and pH in the range from 1 to 2. Americium is recovered from such a solution by 8% TBP solution in xylene or 20% D2EHPA solution in decane; the distribution coefficient of Am^{3+} being more than 100. Americium is re-extracted from TBP by 0.01M acid solution, from D2EHPA by 5M HCl. Due to this process americium is separated from the large amounts of aluminium and from the fission products of I and II groups (Cs, Sr, Ba).

The second stage is the preliminary decontamination of americium from the fission products extracted along with it during the first stage. Therefore the re-extract from TBP is saturated by lithium chloride up to 5M and extracted by 20% TOA solution in xylene (one may reprocess the re-extract from D2EHPA directly). Americium then remains in aqueous phase while Mn,Fe,Co,Zn,Zr,Mo, Tc,Ru,Pd,Cd,Hg and HNO_3 transfer to the solution.

348

- I4 -

As a result the chloride solution is obtained containing mainly americium and rare-earth elements. It should be noted that the total decontamination from γ-activity may be not high, especially with the products of 2-Yearcoling times (the decontamination factor is of order of 2) as americium is separated presumably from the stable isotopes, the final products of decay chain.

Finally, the third stage consists of the americium separation from the rare earth fission products. It occurs due to the americium extraction by 20% TOA from the solution containing 11M LiCl and 0.7M HCl. The difference in the distribution coefficients of americium and lanthanides which is of order of 60 provides the high degree of the americium decontamination.

Ruthenium partially accompanied americium along the whole scheme remains during this operation in organic phase if the re-extraction is performed by 4-6M HCl.

The scheme proposed allows to recover americium with 97% yield when the extraction is performed in the mixer-settler with 13 sections. In this case the decontamination factor of americium from the rare earth elements is 1.10^6, from oesium 2.10^6, from stroncium 4.10^6 and from ruthenium 1.10^6.

348

- I5 -

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346

Table 1

The stability Constants of the Am^{3+} and Cm^{3+} and Some Rare Earth Element Complex Ions with Inorganic Addends.

Complex ion	μ	β	β_0	Complex ion	μ	β	β_0
$Am\ NO_3^{2+}$	1,0	4,0	-	$Ce(SCN)_3^0$	5,0	0.52	-
$Cm\ NO_3^{2+}$	1,0	3,7	-	$AmSO_4^+$	0.75	60,5	$4.85.10^3$
$Am\ SCN^{2+}$	0,5	4,6	40,8	- " -	1.5	58	-
- " -	5,0	1,74	-	$Am(SO_4)_2^-$	1.5	$1.3.10^2$	-
$Am(SCN)_3^0$	5,0	0,91	-	$CmSO_4^+$	0.75	56	$4.5.10^3$
$CmSCN^{2+}$	0,5	4,7	42,2	$Cm(SO_4)_2^-$	0.75	83	$2.9.10^4$
- " -	5,0	1,86	-	$AmH_2PO_2^{2+}$	0.2	49	$3.2.10^2$
$Cm(SCN)_3^0$	5,0	0,99	-	$Pm\,H_2PO_4^{2+}$	0.2	49	$3.2.10^2$
$Ce\ SCN^{2+}$	0,5	3,9	34,6	$Y\,H_2PO_4^{2+}$	0.2	69	$4.5 \cdot 10^2$
- " -	5,0	1,25	-				

Table II

The Stability Constants of the Organic Complexes of Am^{3+} and Cm^{3+}

Complex ion	μ	β	β_0	Complex ion	μ	β	β_0
$AmC_2O_4^+$	0.2	$9,8.10^5$	$9,8.10^6$	$Am(Oxib)_3^0$	0,5	$1,4.10^5$	$I,I.10^7$
$Am(C_2O_4)_2^-$	0,2	$1,4.10^{10}$	$1,4.10^{10}$	$CmOxib^{2+}$	0,5	$2,7.10^2$	$2.5.10^3$
$CmC_2O_4^+$	0,2	$9,1.10^5$	$9,1.10^6$	$Cm(Oxib)_2^+$	0.5	$5,1.10^4$	$2,0.10^6$
$Cm(C_2O_4)^-$	0,2	$1,4.10^{10}$	$1,4.10^{11}$	$Cm(Oxib)_3^0$	0.5	$1,7.10^5$	$1,4.10^7$
$AmLact^{2+}$	0,5	$5,9.10^2$	$5.3.10^2$	$AmAc^{2+}$	0,2	$1,4.10^2$	-
$Am(Lact)_2^+$	0,5	$4,4.10^4$	$1.7.10^6$	- " -	0,5	$2,0.10^2$	-
$Cm(Lact)^{2+}$	0,5	$6,1.10^2$	$5,5.10^3$	- " -	1.0	$1.2.10^2$	$8,3.10^2$
$Cm(Lact)_2^+$	0,5	$3,5.10^4$	$1,4.10^6$	$Am(Ac)_2^+$	0,2	$6.7.10^3$	-
$AmOxib^{2+}$	0,5	$2,4.10^2$	$2,2.10^3$	- " -	0,5	$6.5.10^3$	-
$Am(Oxib)_2^+$	0,5	$4,7.10^4$	$1.8.10^6$	- " -	1.0	$4,2.10^3$	$1.3.10^5$

<u>Table III</u>

The Equilibrium Constants of the Extraction of Americium,

Curium and Nitric Acid by Neutral Phosphororganic Compounds

Extractant		K_o		
Formula	Nomenclature	Am	Cm	HNO_3
1. $(C_8H_{17}O)_3PO$	TOP	0.3	0.25	0.9
2. $(iC_8H_{17}O)_3PO$	TiOP	0.2	0.2	0.7
3. $(iC_8H_{17}O)_2(C_6H_4CH_3)PO$	DiOEKP	0.02	0.02	0.42
4. $(iC_8H_{17}O)(CH_3C_6H_4O)(CH_3)PO$	iOKEMP	1.3	1.85	1.25
5. $(iC_8H_{17}O)(CH_2Cl)PO$	DiOEClMP	-	-	0.22
6. $(iC_4H_9O)_2C_8H_{17}PO$	DiBEOP	2.6	2.6	1.1
7. $(C_8H_{17}O)_2(CH_2Cl)PO$	DOEClMP	4.2	2.8	1.75
8. $(iC_4H_9O)_2C_9H_{19}PO$	DiBENP	5.4	5.4	1.9
9. $(iC_4H_9O)_2C_{10}H_{21}PO$	DiBEDP	2.7	2.7	1.1
10. $(iC_8H_{17}O)_2C_6H_5PO$	DiOEPP	0.08	0.08	0.38
11. $(C_6H_5)(CH_2Cl)(C_4H_9O)PO$	BEPClMP	-	-	0.02
12. $(C_8H_{17})(CH_3)(C_8H_{17}O)PO$	OEMOP	1200	1200	4.0
13. $(C_4H_9)_2(C_4H_9O)PO$	BEDBP	1800	1100	6.6
14. $(C_4H_9)_2(C_8H_{17}O)PO$	OEDBP	2060	2200	7.4 5.0[x)
15. $(C_4H_9)_2(iC_8H_{17}O)PO$	iOEDBP	2500	2900	4.1[x)
16. $(C_4H_9)(C_6H_5)(C_4H_9O)PO$	BEBPP	45.0	38.0	2.8
17. $(C_4H_9)(C_8H_{17})(C_8H_{17}O)PO$	OEBOP	1600	1800	5.2
18. $(C_8H_{17})_2(C_8H_{17}O)PO$	OEDOP	580	506	4.2
19. $(C_8H_{17})_3PO$	TOPO	3000	3000	14.0
20. $(iC_8H_{17})_3PO$	TiOPO	100	100	3,8

x) Decane was used as diluent

348

- 18 -

Table IV

The Am^{3+} and Pm^{3+} Distribution Coefficients for the
Extraction by 20% TBP, TOPO and DAMP from the LiCl
Solutions (pH=I)

Concentration, mole/l	TBP in sintin		TOPO in decane		DAMP in sintin	
	Am	Pm	Am	Pm	Am	Pm
2	–	–	–	0.035	–	–
4	–	–	0.64	I.I	–	–
6	–	–	3.0	3.6	0.I2	0.98
8	–	–	I0.3	7.2	I.0	5.4
I0	0.77	0.74	–	–	2.7	22.0
II	4.6	2.3	–	–	3.8	40.0
I2	I7.3	6.3	22.0	23.0	4.6	62.0

Table V

The Distribution Coefficient of Am and Pm for the Extraction
by 0.2M D2EHPA and M2EHPA Solutions in Decane from the Solution
LiCl + 0.05M HCl

Concentration, of LiCl, mole/l	D2EHPA		M2EHPA	
	Am	Pm	Am	Pm
0.0I	38.0	230	–	–
0.I	23.0	200	–	–
0.5	20.2	I03	–	–
I.0	II.7	84	2I5	–
5.0	0.68	3.2	35	67
9.0	0.08	0.54	I5	30
I3.0	0.07	0.45	0.9	II

348

- 19 -

Table VI

The Am^{3+}, Ce^{3+} and Pm^{3+} Distribution Coefficients for the Extraction by TBP, TOPO and DAMP from the Thyocyanate Solutions

Concentration of NH_4SCN, molt/I	25% TBP in decane			20% TOPO in decane			20% DAMP in decane		
	Am	Ce	Pm	Am	Ce	Pm	Am	Ce	Pm
0	-	-	-	0.2I	I,5	4,2	-	-	-
$5.I0^{-4}$	-	-	-	0.03	0.75	4.25	..	-	-
$I.I0^{-3}$	-	-	-	0.04	2.4	5.04	0.003	-	-
$5.I0^{-3}$	-	-	-	0.5I	48	23.4	0.004	0.0I46	0.0I25
0.0I	-	-	-	I.54	480	208	0.I06	0.048	0.049
0.05	0.0I2	0.024	-	400	500	300	I.75	I.88	I.0
0.I	0.II	0.II	-	550	550	400	I2.2	4.7	4.6
0.5	4.2	0.7	0.4I	-	-	-	-	-	-
I.0	I0.0	I.0	I.2	-	-	-	-	-	-
2.0	2I	3.7	4.0	-	-	-	-	-	-
3.0	48	I3.0	II.0	-	-	-	-	-	-
4.0	95	37.0	20	-	-	-	-	-	-
5.0	I50	90	38	-	-	-	-	-	-

Table YII

The Am^{3+}, Ce^{3+} and Pm^{3+} Distribution Coefficients for the Extraction by 0.02M D2EHPF and M2CHPA from the Thyocyanate Solutions

Concentration of NH_4SCN, mole/l	D2EHPA			M2EHPA		
	Am	Ce	Pm	Am	Ce	Pm
0.I	20	I9.8	I30	$I.2.I0^3$	-	$3.6.I0^3$
0.5	9.5	-	89	-	-	-
I.0	8.4	6.5	43.6	39.4	-	I02
2.0	-	3.5	24.3	II.0	II.8	32.2
4.0	-	I.0	I2.6	3.I	2.9	I6.6
5.0	0.77	-	-	-	-	-
6.0	-	0.49	II.5	I.2	I.2	I2.I
8.0	0.44	0.29	I0.3	0.63	0.48	I0.8

348

- 20 -